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(54) IMPROVEMENTS IN OR RELATING TO RETAINING RINGS

(71) We, WALDES KOHINOOR INC., of 47—16 Austel Place, Long Island City, New York 11101, United States of America, a corporation organised and existing under the laws of the State of New York in the United States of America, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

The present invention relates generally to improvements in retaining rings adapted, when assembled in a circumferential groove machined or otherwise provided therefor in the surface of a carrier member such as a shaft, spindle, etc. (external form) or in the surface of a housing bore (internal form) to provide an artificial machine-element or part locating and/or retaining shoulder projecting from the shaft periphery or from the housing bore-surface. More particularly, the invention is directed to an improved retaining ring capable of functioning as aforesaid and characterized by a ring body which may be so designed as to deflect to a greater degree than conventional retaining rings, without exceeding the maximum allowable stress for the ring material, and in such manner as to increase or decrease the ring circumference, while at the same time providing a substantial increase in the effective section height of the ring body and of the shoulder formed thereby when the ring is assembled in a circumferential shaft or housing-bore groove of normal depth. Also, properly designed rings of the present invention may be effective, i.e. provide substantial shoulder heights, when assembled in grooves which are deeper than normal.

In particular, the present invention relates to a modification of the invention disclosed in the specification of our United Kingdom Patent No. 1,441,467.

Stated briefly, the modified retaining ring according to the present invention may provide an improved design (both external and internal forms) which may overcome in large measure the disadvantages of retaining rings constructed according to the conventional designs and which in addition may enable deflection to a greater degree, whereby the ring is less likely to take on a permanent set than conventional tapered retaining rings; which may make possible, by virtue of a capacity to deflect to a greater degree as aforesaid and in such a manner as to increase or decrease its circumference, the accommodation of a range of shaft and housing-bore diameters with fewer sizes of retaining rings; which may provide a retaining ring whose ring body, rather than being continuously arcuate or substantially so from end-to-end, instead comprises a plurality of serially connected radially inwardly and radially outwardly directed portions having common connecting arms which extend divergently from and connect arcuate "beams" of said portions in series with one another, thereby supplying greater effective shoulder height than is possible with conventional retaining rings; and which may provide a retaining ring as aforesaid wherein the ring is rendered non-planar by virtue of its arcuate "beams" being bevelled along their groove-seating edges in such a manner as to take up end-play upon the ring being assembled in its groove.

To appreciate the advantages of a retaining ring having the capability of deflecting to a greater degree than conventional tapered retaining rings without taking on an excessive permanent set and in such manner as to increase (external form) or decrease (internal form) the circumferential length of the ring body, it may be helpful to sketch briefly the development of the retaining ring art leading to the present invention, as follows:

The oldest retaining rings still in use to retain machine parts on shafts, etc., or in housing bores are rings of uniform radial width made of coils of wire. Under stress, such rings do not deform uniformly circularly but instead they deform elliptically, and hence under stress they do not seat uniformly against the bottoms of the grooves in which they are conventionally assembled. Also, these rings are severely limited as to their

radial widths (which are relatively small) and to use in grooves of shallow depth.

In the specification of U.S. Patent No. 1,758,515 (reissued as No. 18,144) of Heiermann, there is disclosing a tapered retaining ring, i.e. a ring having radial widths which diminish progressively from a relatively wide middle portion towards its open ends. While the tapered ring of Heiermann, by its capability of deforming substantially circularly under stress, widened the fields of safe application of retaining rings to a considerable degree by providing a ring body having greater radial width than possible with uniform radial width rings and thereby a more effective parts-retaining shoulder without becoming loose in its groove in consequence of a permanent set, provided of course that during assembly and disassembly the elastic limit of the ring body material was not exceeded, such tapered retaining rings could be assembled only in relatively shallow grooves, resulting in proportionately limited thrust load capacities of the ring-in-groove assemblies employing same.

The above-mentioned limitations resulted in the art developing further to the extent as evidenced by the disclosure of "pre-stressed" retaining rings, i.e. U.S. Patent Specification No. 2,861,824 for the internal form rings, and U.S. Patent Specification No. 2,982,165 for the external form rings. These "pre-stressed" retaining rings were characterized by increased radial widths and by diameters requiring a moderately increased (as compared to the Heiermann rings) expansion or contraction in the course of their first assembly, consequent to which they took on a predetermined slight permanent set. Such ring design made possible the installation of the pre-stressed ring in deeper shaft or housing-bore grooves, in turn resulting in substantial increases of thrust load capacity of the ring-in-groove assemblies as compared to the ring-in-groove assemblies employing Heiermann rings.

As far as was then known, the aforesaid deeper groove was the maximum depth of groove in which any and all retaining rings could be assembled. That is to say, while the want therefor may have been present, a pre-stressed ring designed to be installed in a groove of greater depth than said maximum was considered to be impractical if not impossible of attainment because the bending characteristics of the pre-stressed rings were too limited. Nor could the want for a ring designed to provide the substantially higher shoulder be satisfied, because conventional designs of pre-stressed rings would be too stiff to handle if their radial widths were increased to the degree satisfying the higher-shoulder-want. Further, and equally important, the higher shoulders would require such increased radial widths as would invariably result in permanent set and looseness of the rings in even the aforesaid "deeper groove" achieved with the ring of Specification No. 2,861,824.

In the foregoing recital of the development of the retaining ring art as documented in the patents aforesaid must be added the knowledge that retaining rings generally, when expanded or compressed, are subject to circumferential stresses which, occurring in the form of tensile and/or compressive stresses acting on the circumferential ring fibres at any section of the ring, result from the forces applied to expand or compress such rings, which forces result in a bending moment acting on any section of the ring. It is these bending moments which cause a change in the curvature of such retaining rings to result in their expansion or compression. While the circumferential stresses resulting from the bending moments acting on sections around the ring body will in theory cause an elastic lengthening or shortening of the fibres of the ring material, no consideration or study was given to the utilization thereof, nor was any purposeful structuring of the ring body designed to increase or decrease the circumferential length thereof to a significant degree.

According to the present invention, there is provided a retaining ring for insertion in a circumferential groove provided therefor in the surface of a carrier member, such as a shaft or housing bore, to form a parts-retaining and/or locating shoulder, the ring comprising an open-ended ring body having a plurality of alternately radially outwardly and radially inwardly directed portions each comprising a respective beam and common connecting arms extending divergently from and connecting the beams in series with one another, the beams having radial widths which decrease progressively from a line radially bisecting the middle portion of the ring body and being so arranged that the inner or outer circumference of the beams of the outwardly directed portions is concentric with respectively the outer or inner circumference of the beams of the inwardly directed portions, and the connecting arms being of such length and angular disposition with respect to the beams which they connect that forces applied to the ring body to expand or compress the body act through the beams connected by each arm to produce bending moments effective to cause deflection of the arms in such direction as to increase or decrease the circumferential length of said portions and thus of the ring body.

Preferably, the other circumferences of the beams are eccentric with respect to said concentric circumferences.

The ring may be constructed as an external ring to seat along its effective inner edge in an outwardly opening groove of a shaft, in

which case the ring may be provided on said inner edge with a bevel enabling the ring to take up end play when assembled. Alternatively, the ring may be constructed as an internal ring to seat along its effective outer edge in an inwardly opening groove provided in a housing-bore surface, in which case the ring may be provided on said outer edge with a bevel enabling the ring to take up end play when assembled.

Embodiments of the present invention will now be more particularly described with reference to the accompanying drawings, in which:

Fig. 1 is a front elevation of a known form of external retaining rings, having a uniform shoulder height;

Fig. 2 is a front elevation of a known form of internal retaining ring, having a uniform shoulder height;

Fig. 3 is a front elevation of an external retaining ring according to a first embodiment of the invention;

Fig. 4 and 5 are alternative sections on the line Y—Y′ of Fig. 3;

Fig. 6 is a front elevation of an internal retaining ring according to a second embodiment of the invention;

Figs. 7 and 8 are alternative sections on the line Y—Y′ of Fig. 6;

Figs. 9, 10 and 11 are front elevations of known forms radially assembled retaining rings;

Fig. 12 is a front elevation of an external, radially assembled retaining ring according to a third embodiment of the invention;

Figs. 13 and 14 are alternative sections on the line Y—Y′ of Fig. 12 and Fig. 17;

Figs. 15 and 16 are schematic elevations of part of the ring of Fig. 3, 12 or 17 illustrating the behaviour of the beams and connecting arms of the ring under force applied to expand the ring,

Fig. 15 showing the ring part in unstressed state and

Fig. 16 the ring part in stressed state; and

Fig. 17 is a front elevation of an external, radially assembled retaining ring according to a fourth embodiment of the invention.

Referring now to the drawings, there are shown in Figs. 1 and 2 typical tapered section retaining rings of the so-called "inverted" construction as known in the art. The main purpose of this construction is to provide a uniform shoulder height when the ring is used as a positioning and/or retaining member in a groove in the surface of a shaft or of a bore in a housing. In an external ring, as shown in Fig. 1, this is done by making the outside contour of the ring a circle 10 which is concentric with a second circle 11, circle 11 defining the contours of inside edges 14 and 15 respectively of lug portions 12 and 13 of the ring. Circles 11 and 10 have their centres at point *a*. A third circle 16, with its centre at *b*, is tangent to circle 11 at point *c* on diameter Y—Y′ and this circle defines tapered bending portions 17 and 18 of the ring. The maximum radial width of the tapered bending portions is *c—d* (that is, the distance from point *c* to point *d*, *d* being the point of intersection of circle 10 with diameter Y—Y′ as shown in Fig. 1). Since this ring construction provides a uniform shoulder height it follows that the radial width of lug portions 12 and 13 is also *c—d*. Further, lug edges 14 and 15 and point *c* will contact the bottom of the groove when the ring is installed.

It is known that the amount the ring of Fig. 1 can be spread during installation, and consequently the maximum depth of groove in which it will seat tightly, will be determined by the maximum radial width *c—d* and the ring neutral diameter. Therefore *c—d* is subject to a maximum limit as determined by flexibility requirements of the ring and by the ring size. Further, it must be noted that lug portions 12 and 13 have holes 19 and 20 or other apertures which may be engaged by the tips of pliers for the purpose of spreading the ring so that it may be installed. The holes must be of reasonable size to permit the use of sufficiently strong plier tips, that is tips of adequate diameter which will be capable of spreading the ring without breaking. Since such rings are normally produced by stamping there must be sufficient material, for example between edge 14 and hole 20, so that the stamping tools do not have walls which are too thin and which will not stand up under conditions of mass production. Therefore, *c—d* is subject to a minimum limit as determined by production requirements. Further, it should be noted that when the ring is seated in a groove, the distance between edge 14 and hole 20 (or edge 15 and hole 19) if smaller than the groove depth, will result in a portion of the holes 19 and 20 being covered by the groove wall. This makes assembly and disassembly very difficult, because covering part of the holes prevents free insertion and removal of the tips of a spreading tool.

The result of these limitations for uniform shoulder height rings in the present state of the art is generally lug holes that are somewhat smaller than desirable, and maximum radial widths somewhat larger than desirable for any ring size. These conditions lead to limited flexibility for such rings resulting in limited groove depths, and production difficulties wherein stamping punches for the holes or apertures break down. Since it is preferable, from the aspect of interchangeability, to use such an inverted construction ring in a groove of the same diameter as for a conventional tapered section retaining ring of the same size, the result is a looser fit of

the ring in its groove with all the known resulting disadvantages, such as reduced thrust load capability and the impossibility of seating such rings in grooves of depths suitable for conventional bevelled tapered section retaining rings. As is well known, bevelled rings require a greater groove depth than non-bevelled rings in order that a reasonable degree of take-up may be available. It is well known that inverted rings in the present state of the art are generally unsuited for use as bevelled rings.

Fig. 2, which illustrates the internal type of known inverted ring, exhibits similar features except that the ring has a larger gap in order that the ring may be compressed until lugs 21 and 22 touch to allow the ring to be installed in a groove in a bore or housing. The same limitations as for the external ring apply here as regards maximum section *e—f*, radial width of lugs 21 and 22, and apertures 23 and 24. The applicability of the ring to grooves deeper than for conventional internal tapered section rings does not exist and the ring is unsuited, therefore, for use as a bevelled ring where adequate take-up is required.

It should be noted from Figs. 1 and 2 that the lug portions of both rings (12 and 13 in Fig. 1, and 21 and 22 in Fig. 2) are elongated and represent a significant portion of the ring circumference. This is so that there will be a reasonable amount of ring face in contact with the groove wall in the lug area. Since the lug portions are inflexible compared to the adjacent reduced bending portions (25 and 26 in Fig. 1, and 27 and 28 in Fig. 2), a significant portion of the ring circumference is not available for flexibility, that is the circumferential length of the tapered portions are reduced. This further reduces the expandability of the ring of Fig. 1 and the contractability of the ring in Fig. 2, and further limits the groove depth in which such rings may be seated.

Referring now to Figs. 3 to 5, there is shown an external retaining ring according to a first embodiment of the invention, the ring being of tapered construction to provide a uniform shoulder height when used as a parts positioning and/or retaining member in a groove on a shaft. It is also intended to provide for greater ring deflection than existing uniform shoulder height ring designs and to be capable of seating in grooves of comparable depth to those which are utilized for tapered retaining rings as previously described in United Kingdom Patent Specification No. 1,441,467, thereby to be capable of bevelled construction so as to take up end play when assembled in a bevelled groove, said end play takeup being greater than that for conventional tapered section bevelled rings. Finally it is intended that the ring be capable of providing higher uniform shoulder heights than is possible with existing convential "inverted" tapered section rings.

In Fig. 3 the ring is shown with the outer edges of outer arcuate beams thereof defined by a circle 1 with its centre at 0. The inner edges of inner arcuate beams of the ring lie on a circle 4 whose centre is also at 0. Therefore, the two circles are concentric and the effective radial width (i.e.: the distance on any radius, drawn from 0, between the points of intersection of such a radius with circles 1 and 4) at any point around the ring circumference is constant (this distance is B—C on radius O—A in Fig. 3).

To taper the outer arcuate beams, their inner edges are made to lie on a circle 2 whose centre is at D, eccentric to O. Similarly, to taper the inner arcuate beams, their outer edges are made to lie on a circle 3, with its centre at G, also eccentric to O but in the opposite direction on line Y—Y'. By this construction, there is achieved tapering of the inner and outer arcuate beams from a maximum value of beam radial width at the ring mid-section (h_{max}—outer arcuate beam) or adjacent the ring mid section (h'_{max}—inner arcuate beam) to a minimum value (h_{min}—outer arcuate beam, h'_{min}—inner arcuate beam) in the area of the ring gap. The effective radial width (H_{EFF}) of the ring, however, is constant around the ring circumference (i.e.: H_{EFF}=B—C). Effective shoulder heights up to 5 times those of conventional rings are possible in the case of the tapered retaining ring. Arcuate beam radial widths may vary from ring material thickness to 3½ times material thickness and the angle of inclination of the connecting arms with respect to a radius, which is struck from the ring centre O and which extends through the mid-length point of the outer arcuate beam with which said arm connects, may vary from 7° to 20°. The width of the connecting arms (W in Fig. 3) can be from 1 to 3 times ring material thickness. The action of the arms in this ring construction is the same as that described for the ring of Specification No. 1,441,467. The effective radial width of the ring should be at least equal to the sum of h_{max} and h_{max}' for effective bending and circumferential change when the ring is spread, i.e.,

$$H_{EFF} \geqq h_{max} + h'_{max}$$

Stated another way:

All points on the circle 3 containing the outer edges 105, 106, 107, 108 of the inner arcuate beams, which exist as real points on the ring, must be inside the circle 2 containing the inner edges 109, 110, 111, 112 of the outer arcuate beams, with the exception of point 113 on the circle 3 which can lie on the circle 2 (in Fig. 3 point 113

is imaginary, but if there were an inner beam opposite the ring gap this point would be real).

Lug portions 114 and 115 need not be extended circumferentially as shown previously for the lugs in Figs. 1 and 2 because the uniform shoulder tapered ring will seat in a groove bottom along all inner edges 118, 119, 120, 121, 122, etc. of all the inner arcuate beams, thus providing ample groove seating and groove wall contact for resisting thrust loads. Lug height H_L equals H_{EFF} and is large enough so that the holes 116 and 117, for effecting spreading of the ring by a suitable tool, need not be limited in size in the manner of the present art.

There is thus no loss in flexibility due to extended rigid lug portions.

The ring may be made bevelled (at 123 in Fig. 5) or non-bevelled (Fig. 4). Figs. 4 and 5 are sections taken along line Y—Y′ through the ring mid-section for non-bevelled and bevelled rings respectively.

All material pertaining to the use of assembly sleeves and the applicability to many shaft sizes of a single ring in pertinent for the uniform shoulder height ring as well as the ring of Specification No. 1,441,467.

There is, however, a surprising result provided by this construction which may enhance the function of the uniform shoulder tapered section ring as compared to a tapered ring and to the rings of the prior art (Figs. 1 and 2). Clearly uniform section rings of the prior art are less flexible than comparable tapered section rings. They generally have no adaptability to groove depths sufficient to permit their use as bevelled rings.

With the tapered construction of the ring of Figs. 3 to 5 with uniform effective section height there is exactly the opposite result. If the ring in Fig. 3 has h_{max} equal to h_{max} of the ring in Fig. 1 of Specification No. 1,441,467, and if H_{EFF} in Fig. 3 is equal to the effective maximum section opposite the ring gap of the ring in said Fig. 1, and further if the inside diameter of the ring in Fig. 3 is the same as that of the ring in said Fig. 1, then for such a construction in rings with equal numbers and width W of the connecting arms, the ring in Fig. 3 may be more flexible than the ring in said Fig. 1. The reason for this lies in the length of the connecting arms. All the arms in Fig. 3 have the same length (i.e. E—F). In the ring in said Fig. 1 only the arms adjoining the arcuate beam opposite the ring gap have maximum length. Further around the ring circumference in said Fig. 1, the arms get shorter bcause the effective radial width is reduced. Since the circumferential change in the ring depends on angle ε_1 (Fig. 5 of Specification No. 1,441,467 and since ε_1 is a function of the length of the connecting arms (among other factors), the additional lengths of the arms around the ring circumferences will provide additional circumferential change capability compared to that of the ring in said Fig. 1. This will result in even greater flexibility of the ring, capability to seat in even deeper grooves and capability to handle more shaft sizes than the tapered ring of said Fig. 1. This also means that for rings of equivalent diameter, the section heights (h_{max}, h'_{max}, h_{min}, h'_{min}) of the ring in Fig. 3, may be made larger than those of the ring in said Fig. 1 with the resulting ring having the same deflection capability as the ring in said Fig. 1 but being of a reinforced design. Where a thicker ring is desired, for stiffness under very severe loading conditions, and where h_{min} in said Fig. 1 limits the ring thickness (because thickness should not generally exceed h_{min}) a thicker ring can be fabricated successfully and economically by increasing h_{min} and using the construction in Fig. 3 to maintain equivalent flexibility.

Fig. 6 illustrates the internal version of the uniform shoulder tapered section ring, which acts in the same manner as but inversely to the ring of Figs. 3 to 5. Figs. 7 and 8 are alternative sections on the line Y—Y′ of Fig. 6, Fig. 8 showing the provision of a bevel 123′ on the outer edges of the outer beams. The circles 1′, 2′, 3′ and 4′ correspond to circles 1, 2, 3 and 4 respectively of Fig. 3. The circle centres D′ G′ and O′ also correspond to D, G and O in Fig. 3, and the axes E′—F′ correspond to E—F.

With reference to Figs. 9, 10 and 11, there are shown forms of radially assembled retaining rings, which are assembled into their shaft grooves in a direction perpendicular to the axis of the shaft. Crescent-type rings, according to the specification of U.S. Patent No. 2,491,306, Figs. 7, 8 and 9, have a tapered bending portion extending from the ring mid-section 45 (Fig. 7) to 46 and 46*a* respectively. This tapered portion encompasses 180° of the ring circumference. At each end of the tapered ring portion there is a lug portion 48 or 48*a*, which is rigid and which provides the ring with two groove contacting edges 50 and 50*a*.

Fig. 9 of the accompanying drawings illustrates such a ring. There is noted thereon gap angle α which is the included angle between two radii struck from the ring centre O″ (the centre of the circle which makes up the effective inside circumference of the ring as shown by a dot-dashed line), each of which radii passes through the initial point of contact of the ring inside circumference on one of the lugs with the groove bottom during assembly of the ring (points 31 and 32 in Fig. 9). This included angle is approximately 135°. Since the ring in Fig.

9 has an inside diameter only slightly (1 to 4%) less than the diameter of the groove in which the ring will be assembled (U.S. Specification No. 2,491,306, Col. 5, lines 57 to 61), this type of ring when assembled in its groove will encompass an angle of approximately 220° of groove circumference, that is, the included angle (angle ω plus angles β and β') between points 31 and 32 (Fig. 9) of the ring in the assembled condition. The angles β and β' as shown in Fig. 9 will be approximately 20° in the assembled condition. Examination of Fig. 9 will show that under these conditions it is not possible to allow the groove diameter to vary a significant amount because a small decrease will permit the ring to be easily dislodged from its groove and any significant increase will reduce β and β' of the assembled ring to the point where said included angle will be too small to permit the ring to grip the groove. This is a direct result of angles β and β' being so small, i.e. approximately 20°. It can be seen, therefore, that in this type of radially assembled ring, although the tapered bending portion encompasses most of the ring circumference, the security of the ring in its groove is limited and the groove diameter must be confined to narrow limits.

Figs. 10 and 11 illustrate other types of radially assembled rings where the rigid lug portions make up a greater part of the ring circumference. The ring in Fig. 10 (U.S. Patent 3,595,123) consists of a tapered bending bridge 41 curved inwardly at 42 and 43 to provide added flexibility, and rigid lug portions 44 and 45, which encompass a major portion of the ring circumference. For such rings, angle α in the free state of the ring is approximately 110°. The grooves for such rings have diameters approximately 6 to 8% larger than the inside diameter of the ring. Hence, when such rings are assembled, the angles β and β' in relation to the groove diameter will be approximately 30°. Rings as shown in Fig. 10 have a somewhat greater degree of security in their grooves than the ring of Fig. 9, and can be used in grooves whose diameter have a more ample tolerance than those of the ring of Fig. 9.

Radially assembled rings, generally known as "E-rings", as shown in Fig. 11 (as per U.S. Patents Nos. 2,026,454 and 2,411,761) are very widely used. They have three rigid lug portions 51, 52 and 53, connected by flexible bending portions 54 and 55. In their free state they have an included gap angle α of 120°. When they are assembled in their grooves, angles β and β' would be approximately 25 to 30°, which is similar to the condition for the ring in Fig. 10. Their construction is such that the bending portions 54 and 55 have a somewhat more limited flexibility than the bending portion of the ring in Fig. 10, and such rings have inside diameters which are only from 1 to 4% smaller than the diameter of the grooves in which they are seated. The groove diameters for such rings also must be held to close tolerances.

None of the prior art rings as described above can be used in a manner which would permit the inside diameter of the ring to be varied sufficiently by flexing of the bending arms so that such rings could be used for taking up end play rigidly by bevelling the inside edges of the rigid ring portions and correspondingly the groove walls.

Permissible tolerances on groove diameters for rings of the prior art are generally from ½ to 4% of the groove diameter; in other words, the inside diameter of these rings can vary approximately ½ to 4% of its nominal value in the assembled condition. For larger sizes of radially assembled retaining rings of the prior art, this variation is only from ½ to 1%. On the other hand, in order to provide end play take-up in a reasonable or usable quantity, a minimum variation of 4% would be required; this shows that the prior art radially assembled retaining rings cannot be adapted for such end play take-up.

Referring now to Fig. 12 to 14, there is shown a tapered retaining ring which has been designed to be capable of being radially assembled into a groove and where one ring size is of sufficient flexibility to be usable in grooves of different diameters for one of three purposes, namely:

that the groove diameter can be made to very large tolerances for reasons of economical production

to be usable in grooves of different diameters so that one ring is adaptable to several shaft sizes with the groove diameters varying substantially in correspondence with the shaft diameters

to be usable in different degrees of expansion in a bevelled groove with the ring edges themselves being correspondingly bevelled so as to provide, to a reasonable degree, rigid end play take-up of tolerances in an assembly.

Unlike the rings of the prior art, almost the entire ring body in Fig. 12, as defined by angle ϕ, is made up of outer flexible arcuate bending portions 205, 206, 207, inner flexible arcuate portions 208, 209, 210, etc. and connecting arms 211, 212, 213, 214, 215. Only the small hook-like lug portions 216 and 217 are outside the bending zone of the ring body, and these lug portions represent less than 10% of the ring circumference. Angle ϕ may be as large as 280°, with the result that angle α can be as small as 80°, that is, significantly smaller than for any of the prior art radially assembled rings.

The construction of the ring body por-

tions, i.e. arcuate beams and connecting arms, has been previously described in specification No. 1,441,467 and follows the various proportions and parameters described therein as related to beam radial widths, connecting arm lengths, angles of inclination, etc. The ring of Figs. 12 to 14 results in an assembly where the ring forms a tapered shoulder. The inner edges of the outer beams and the outer edges of the inner beams are defined by concentric circles 2″ and 3″ respectively, and the outer edges of the outer beams and inner edges of the inner beams by circles 1″ and 4″ respectively, the circles 1″ and 4″ being eccentric to the circles 2″ and 3″. An alternative design may, however, follow the principles of ring construction as outlined in connection with Figs. 3, 4 and 5, in which case a radially assembled ring of uniform shoulder height, as shown in Fig. 17, is achieved. In this design the outer edges of the outer beams and the inner edges of the inner beams are defined by concentric circles 1‴ and 4‴ respectively, and the inner edges of the outer beams and the outer edges of the inner beams by circles 2‴ and 3‴ respectively, the circles 1‴ and 4‴ being eccentric to the circles 2‴ and 3‴.

If a radially assembled ring is assembled in a groove 8% larger than the free diameter of the ring, angles β and β' would normally (according to the principles for previously known radially assembled rings wherein the included circumferential angle of the assembled ring varies inversely as the percentage of diameter increase of the ring) be equal to 39° (where ϕ for the free ring is 280°) when the ring is assembled. In the case of the retaining rings of the present invention, however, it has been shown how circumferential change (increase for external rings) takes place when such rings are expanded. Hence, for the radially assembled retaining rings, angles β and β' for the assembled ring will be greater than the amount normally calculable by previously known methods, i.e. greater than 39°. This means that a much greater degree of security is provided by the radially assembled tapered rings in that angles β and β' can be 30% greater (or more) for such rings than for any previously known radially assembled rings. Tests have verified these figures.

It should be further noted that due to their greatly increased flexibility, radially assembled tapered retaining rings of the present invention can be used as bevelled rings to provide rigid end play take-up by providing a bevel 220 along the planar edges of the inner arcuate beams to contact a correspondingly bevelled groove wall. As previously stated, this added flexibility may be used in yet another manner, that is, to provide a ring which can be used as a radially assembled ring in grooves of different diameters on correspondingly different shaft sizes. The bevelled version of the ring of Fig. 12 or Fig. 17 is shown in Fig. 14, which is a section on the line Y—Y′. Fig. 15 shows a similar section for the non-bevelled ring.

The ring shown in Fig. 12 or Fig. 17, in addition to being assembled radially into its groove, may also, because of its very flexible construction, be used as an axially assembled ring. Lug portions 216 and 217 may be provided with apertures or openings 218 and 219 respectively, into which may be inserted plier tips or the tips of other special tools normally used for expanding retaining rings. The ring may be spread and assembled over a shaft axially and into position in which it may be seated in its groove.

Tests have shown that such a radially assembled ring can be used in a groove where the diameter varies by as much as 6% of the nominal inside diameter of the ring. This may provide for conditions of end play take-up equal to and exceeding that of known bevelled axially assembled rings where the rings flex 3 to 4% under various take-up conditions. For the percentages given above (6% vs. 3%) a take-up increase of 80% over known bevelled ring construction may be possible.

As an example of possible variations in a retaining ring according to the present invention, it is stated that the ring body may comprise 3 to 15 inwardly and outwardly directed portions, depending on ring size; that the arms connecting the beam opposite or substantially opposite the ring gap may each have a length (which may be defined as the length along its neutral axis between the points of intersection of said axis with the outer edge of the outer beam and the inner edge of the inner beam connected by said arm) at least equal to twice the radial width of that beam, which radial width may be in the range of ring-material thickness to 3½ times ring-material thickness; and the angle of inclination of each arm with respect to a radius of the ring body bisecting the outer beam with which said arm is connected may be from 7 to 20°.

It is observed that while the number of connected beams making up the ring body may vary widely, i.e. from 3 to 15 as above, the arcuate length of any one of the beams, either outer or inner edge, is readily determined according to the equation:

$L_o = R_o$ times θ wherein

L_o = the length of said any one arcuate beam under investigation

R_o = the neutral radius of said arcuate beam measured from ring centre

θ = the included angle in radians between radii from the ring centre to the points of intersection of the neutral

axis of said arcuate beam and the neutral axis of the connecting arm at each end of the aforesaid arcuate beam.

Retaining rings of the design of the present invention, in addition to their substantially increased effective radial width and their capability of deflecting to a greater degree (50% or more) than conventional tapered retaining rings, also incorporate structure endowing them with the ability to change, i.e. increase or decrease, their circumferential length to a significant degree under the action of bending moments resulting from the forces applied to the ring ends to spread or contract the ring bodies, for example, in their assembly or disassembly.

More particularly and referring to Figs. 15 and 16, which schematically illustrate the same one of the plurality of radially outwardly directed portions (each consisting of arcuate outer-edge beam 312 and its connecting arms 320a and 320b) of the ring body of Fig. 3, 12 or 17, Fig. 15 depicts said ring body portion (beam and its divergent connecting arms) in its free or unstressed state, whereas Fig. 16 illustrates the behaviour of said portion under the action of bending moments resulting from forces assumed to be applied to the ring-body ends to spread same, for example, in its assembly in and disassembly from a groove.

While the beam is shown in Fig. 16 to have taken on a slight upwardly concave curvature, indicated by solid lines, compared to its original shape, indicated by broken lines, the length of said beam remains essentially unchanged. Examination of its supporting connecting arm positions, however, reveals that under the action of the bending moments M, M'_B (and M_B and M', being the reaction to M and M'_B, respectively), resulting from the forces applied to spread the ring body, the arms *320a* and *320b* have rotated (the arm *320a* throughout a clockwise arc and the arm *320b* throughout a counterclockwise arc), to new angular positions with respect to the neutral axis of the beam 312, the reason therefore being that said moments acting on the ring body portions 312, *320a* and *320b* have effected bending of the beam and rotation of each said arm. The result is an appreciable increase in the distance between lines J—J and K—K (Fig. 15) from L to L′ (Fig. 16).

Since each of the connecting arms of the ring body will undergo a similar rotation under the action of moments M, M'_B (and their reaction moments) which result from spreading forces applied to the ring body, it will be appreciated that the structure of the ring of the present invention is one allowing a substantial increase in the circumferential length of the ring body when such is called for. Thus, in addition to its other advantages, the ring of the present invention may possess the very practical advantage of making possible the accommodation of a whole range of shaft sizes, with substantially fewer sizes of retaining rings.

While not described in the same detail as given above for the external form of the ring of the present invention, it will be understood that the internal ring of Fig. 6 will function in equivalent, albeit inverse, manner. That is to say, ring contracting forces effect a decrease in the circumferential length of the ring body when such is called for.

Numerous advantages as well as economies are possible through proper use of retaining rings constructed according to the present invention. To briefly summarize these advantages, rings of the invention may have substantially increased deflectability, i.e. ability to be expanded (external rings) or contracted (internal rings) without taking on a permanent set, as compared to conventional tapered retaining rings. This enables rings of the present invention to be assembled in deeper shaft and housing-bore grooves than was heretofore throught possible and to provide a substantially higher than conventional parts-retaining shoulder, the substantial length of the connecting arms interposed between and in connecting relation between the outer edge and the inner edge arcuate beams providing the substantial increase in the effective shoulder heights of the ring and also adding to the capability of the ring body to deflect (bend) in manner as to increase its diameter.

Analysis of the ring design also shows that as a result of the aforesaid interpositioning of connecting arms of appreciable length and in connecting relation between the outer-edge and inner edge arcuate beams, an increase or decrease in the circumferential length of the ring body will occur under the action of those same forces which are conventionally applied to expand or contract the ring in its assembly or disassembly. It is explained that such a ring-body response is not only different from but was earlier unknown in the retaining ring art, wherein the only known ring-body response to ring expanding or contracting forces was ring-diameter change, as distinguished from circumferential length change.

When the aforesaid principle is applied to bevelled edge rings, end play take-up by as much as 100% greater than that achieved in the use of conventional bevelled edge tapered rings may be possible.

In addition, with the capability of the internal rings of the present invention to contract to an outer edge diameter substantially less than heretofore without taking on

a permanent set, it becomes feasible to contract such a ring to an outer diameter appreciably less than that of the bore of a housing having the groove in which the ring is to be assembled. Should the bore wall be of a soft material, it is possible to insert a hard metal sleeve in the bore between the bore wall and the contracted ring during the installation of the latter, said sleeve protecting the bore wall from being scored as often previously occurred when installing conventional tapered retaining rings of the internal form.

Such a hard-metal sleeve may be used independently of, or may be formed as an extension on, known manual or automatic internal-ring compressing tools which function to contact rings by forcing same through a tapered orifice, in which case the hard-metal sleeve receives the contracted ring as it leaves the tool thereby protecting the bore wall from being scored or otherwise damaged during ring movement to the plane of the groove.

The same principle but inversely applied may be used to protect the outer cylindrical surfaces of shafts, pins and the like from damage by scoring, etc. during assembly of the external form rings in outwardly opening grooves, the hard-metal sleeve slipped over the shaft end protecting the shaft surface to the same degree as the hard-metal sleeve inserted in the housing bore.

By providing a ring which, in addition to having increased bending or deflection capabilities, is also so structured as to possess the capability of circumferential-length change, substantial economies in industry are attainable, as follows from the fact any one ring size can accommodate a whole range of shaft and housing bore sizes.

WHAT WE CLAIM IS:—

1. A retaining ring for insertion in a circumferential groove provided therefore in the surface of a carrier member, such as a shaft or housing bore, to form a parts-retaining and/or locating shoulder, the ring comprising an open-ended ring body having a plurality of alternately radially outwardly and radially inwardly directed portions each comprising a respective beam and common connecting arms extending divergently from and connecting the beams in series with one another, the beams having radial widths which decrease progressively from a line radially bisecting the middle portion of the ring body and being so arranged that the inner or outer circumference of the beams of the outwardly directed portions is concentric with respectively the outer or inner circumference of the beams of the inwardly directed portions, and the connecting arms being of such length and angular disposition with respect to the beams which they connect that forces applied to the ring body to expand or compress the body act through the beams connected by each arm to produce bending moments effective to cause deflection of the arms in such direction as to increase or decrease the circumferential length of said portions and thus of the ring body.

2. A retaining ring as claimed in claim 1, wherein the length of each arm connected to the beam opposite or substantially opposite the opening between the ring ends, as measured between the points of intersection of the axis of each said arm with the outer edge of the beam of the respectively connected outwardly directed portion and the inner edge of the beam of the respectively connected inwardly directed portion, is at least twice the radial width of that beam.

3. A retaining ring as claimed in claim 2, wherein the radial width of said opposite or substantially opposite beam is in the range of ring-material thickness to 3½ times ring-material thickness.

4. A retaining ring as claimed in any one of the preceding claims, wherein the angular disposition of each connecting arm with respect to the beam of the respectively connected outwardly directed portions, as determined by the angle of inclination of the axis of said arm with respect to a radius of the ring body bisecting said beam, is from 7° to 20°.

5. A retaining ring as claimed in claim 1, wherein the ring is constructed as an external ring to seat along its effective inner edge in an outwardly opening groove of a shaft.

6. A retaining ring as claimed in claim 5, wherein the ring is provided on said inner edge with a bevel enabling the ring to take up end-play when assembled.

7. A retaining ring as claimed in claim 1, wherein the ring is constructed as an internal ring to seat along its effective outer edge in an inwardly opening groove provided in a housing bore surface.

8. A retaining ring as claimed in claim 7, wherein the ring is provided on said outer edge with a bevel enabling the ring to take up end-play when assembled.

9. A retaining ring as claimed in claim 1, wherein the ring body comprises 3 to 15 such inwardly or outwardly directed portions.

10. A retaining ring as claimed in claim 1, wherein the other circumferences of the beams are eccentric with respect to said concentric circumferences.

11. A retaining ring as claimed in claim 1 and substantially as hereinbefore described with reference to Figs. 3 to 5 of the accompanying drawings.

12. A retaining ring as claimed in claim 1 and substantially as hereinbefore described with reference to Figs. 6 to 8 of the accompanying drawings.

13. A retaining ring as claimed in claim 1

and substantially as hereinbefore described with reference to Figs. 12 to 14 of the accompanying drawings.

14. A retaining ring as claimed in claim 1 and substantially as hereinbefore described with reference to Fig. 17 of the accompanying drawings.

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1 477 831 7 SHEETS

COMPLETE SPECIFICATION

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SHEET 1

FIG. 1.

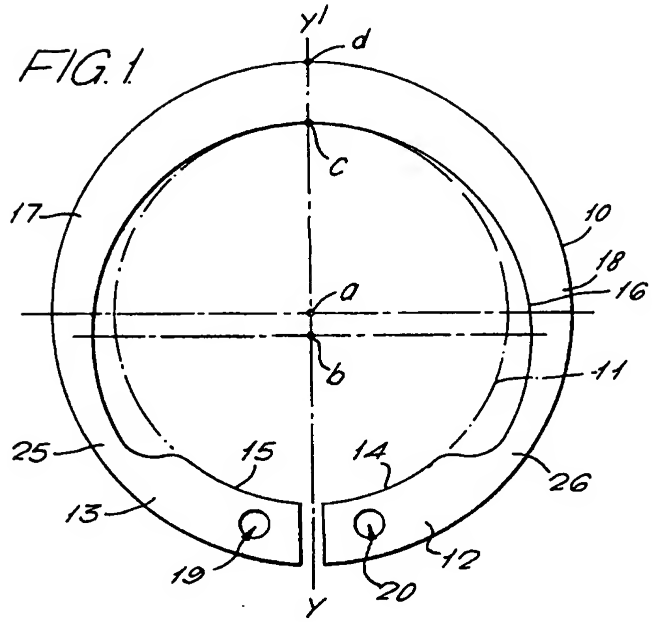
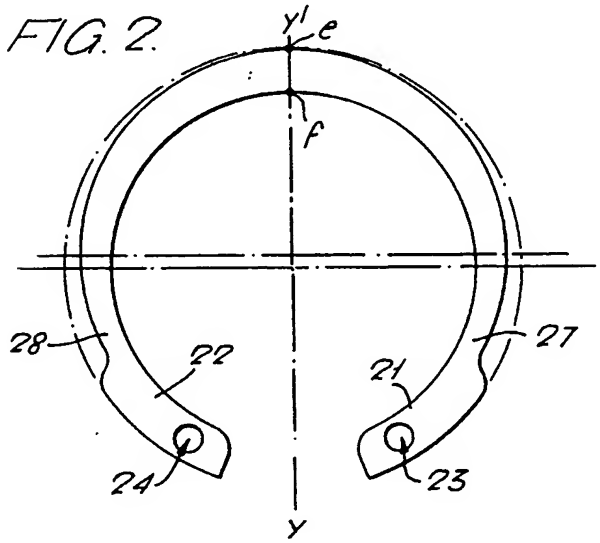


FIG. 2.



1 477 831 COMPLETE SPECIFICATION
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SHEET 2

FIG. 3.

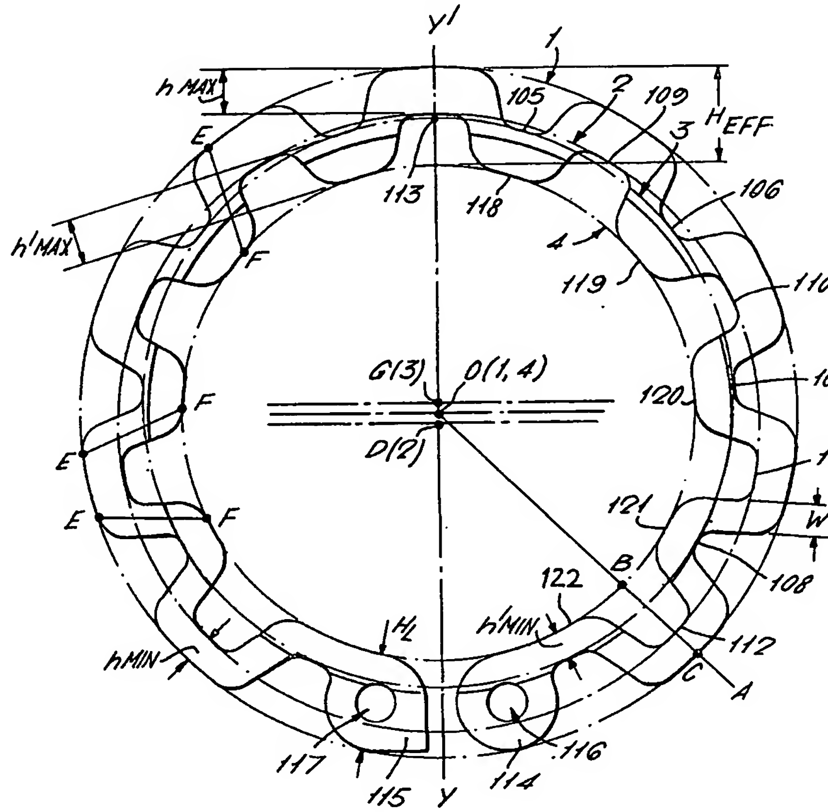

FIG. 4.

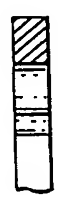

FIG. 5.

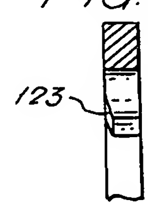

FIG. 6.

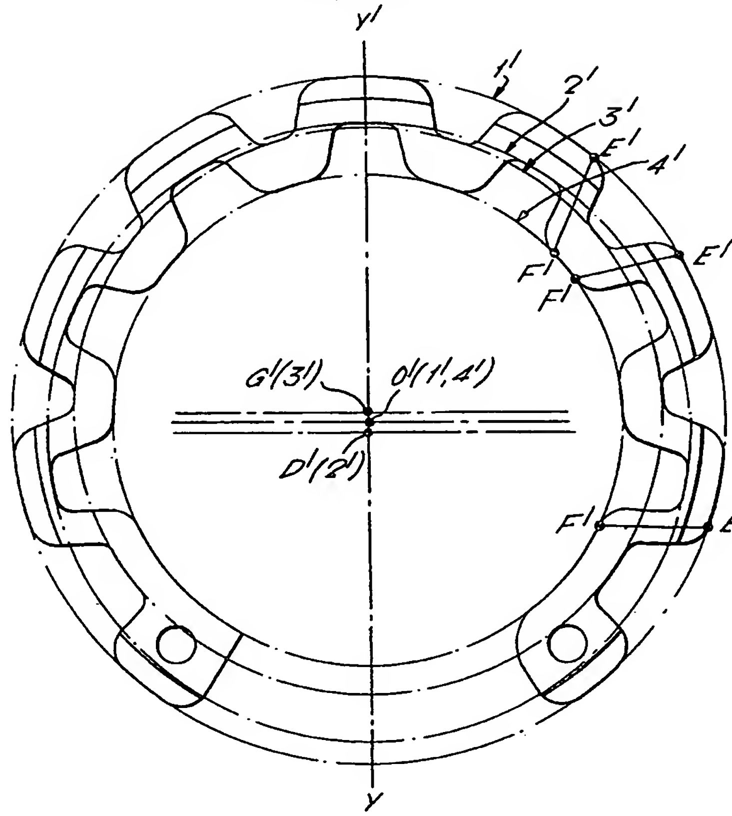

FIG. 7.

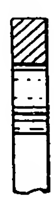

FIG. 8.

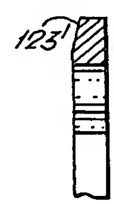

FIG. 9.

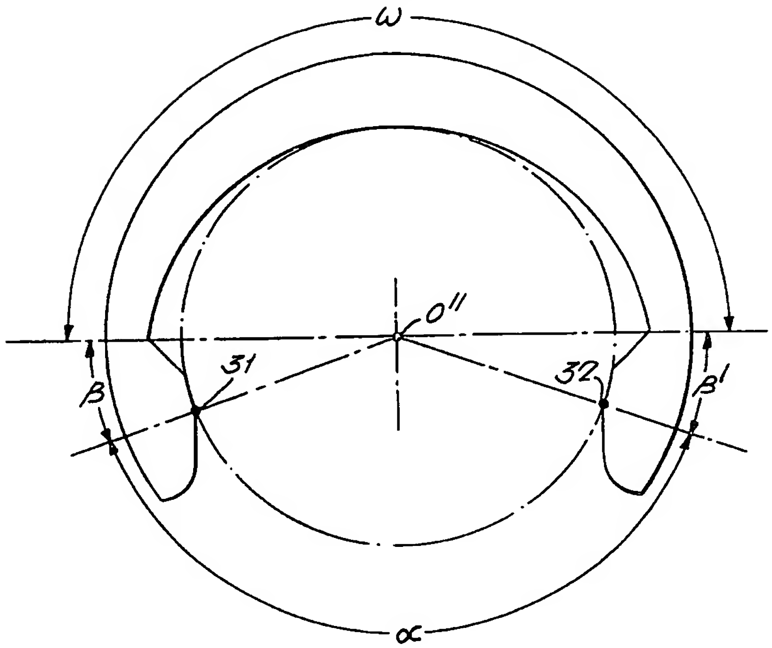

FIG. 10.

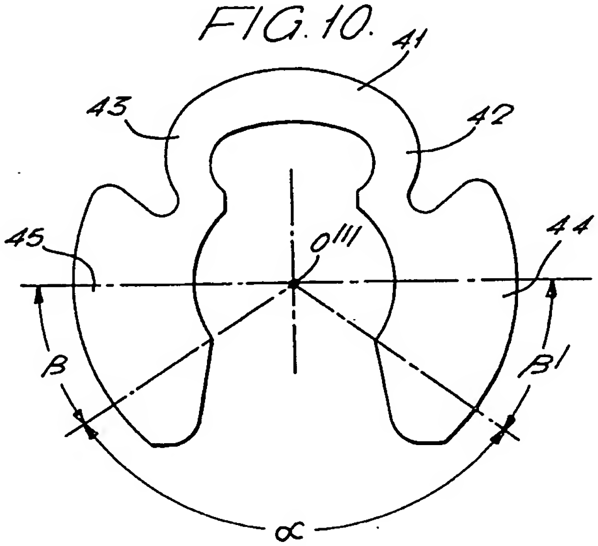

FIG. 11.

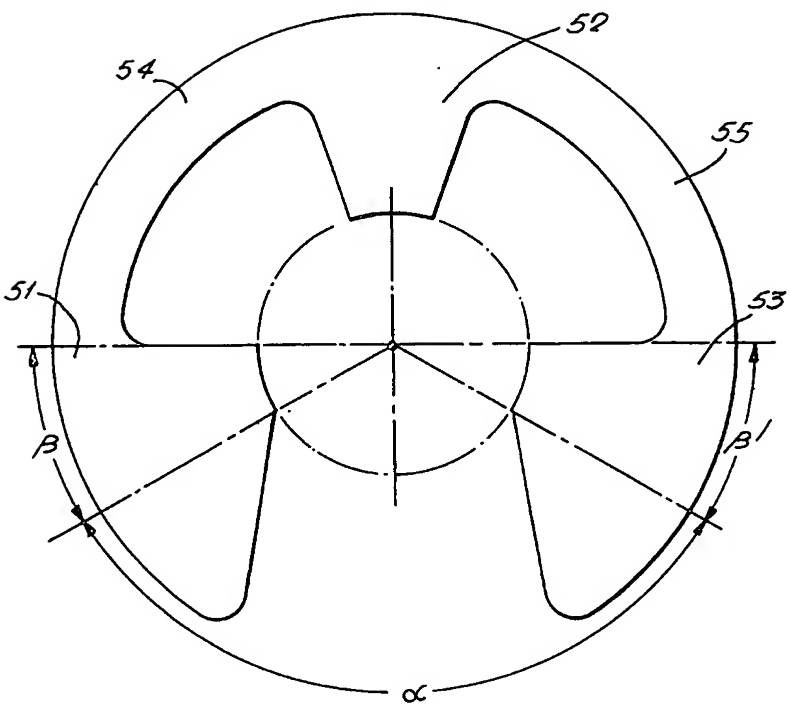

FIG. 15.

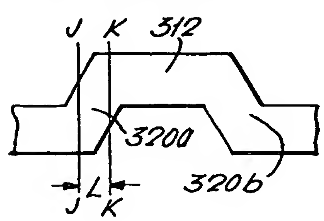

FIG. 16.

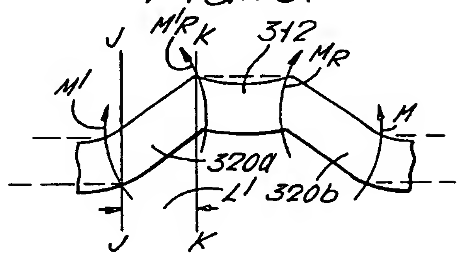

FIG. 12.

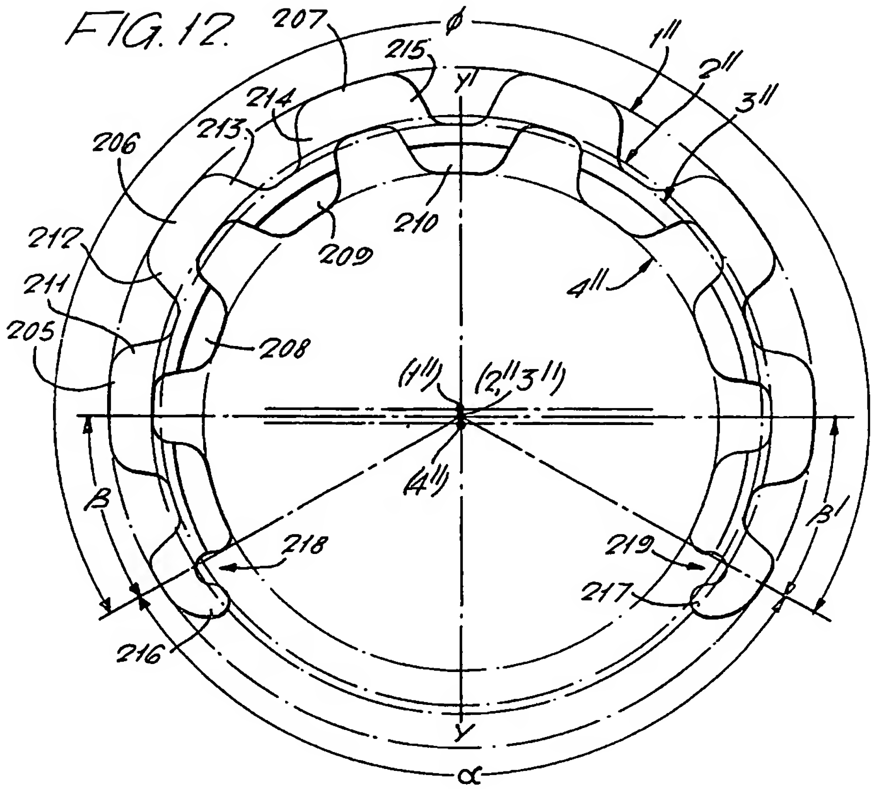

FIG. 13.

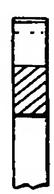

FIG. 14.

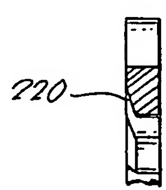

FIG. 17.